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# TECHNICAL MEMORANDUM

## X-186

# TESTS OF AERODYNAMICALLY HEATED MULTIWEB WING STRUCTURES IN A FREE JET AT MACH NUMBER 2

## FIVE ALUMINUM-ALLOY MODELS OF 20-INCH CHORD WITH 0.064-INCH-THICK SKIN, 0.025-INCH-THICK WEBS, AND VARIOUS CHORDWISE STIFFENING AT 2° ANGLE OF ATTACK


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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

WASHINGTON January 1960


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TECHNICAL MEMORANDUM X-186

# TESTS OF AERODYNAMICALLY HEATED MULTIWEB WING STRUCTURES IN A FREE JET AT MACH NUMBER 2

## FIVE ALUMINUM-ALLOY MODELS OF 20-INCH CHORD WITH 0.064-INCH-THICK SKIN, 0.025-INCH-THICK WEBS, AND VARIOUS CHORDWISE STIFFENING AT $2^{\circ}$ ANGLE OF ATTACK*

By Donald H. Trussell and Robert G. Thomson

## SUMMARY

An experimental study was made on five 2024-T3 aluminum-alloy multiweb wing structures (MW-2-(4), MW-4-(3), MW-16, MW-17, and MW-18), at a Mach number of 2 and an angle of attack of $2^{\circ}$, under simulated supersonic flight conditions. These models, of 20-inch chord and semi-span and 5-percent-thick circular-arc airfoil section, were identical except for the type and amount of chordwise stiffening. One model with no chordwise ribs between root and tip bulkhead fluttered and failed dynamically partway through its test. Another model with no chordwise ribs (and a thinner tip bulkhead) experienced a static bending type of failure while undergoing flutter. The three remaining models with one, two, or three chordwise ribs survived their tests. The test results indicate that the chordwise shear rigidity imparted to the models by the addition of even one chordwise rib precludes flutter and subsequent failure under the imposed test conditions. This paper presents temperature and strain data obtained from the tests and discusses the behavior of the models.

*Title, Unclassified.

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## INTRODUCTION

The Langley Structures Research Division has been engaged in an investigation to determine the effects of aerodynamic heating on aircraft structures. As part of this investigation, a series of multiweb wing structures has been tested in a free jet at a Mach number of 2. These multiweb models had 5-percent-thick circular-arc airfoil sections and solid leading and trailing edges.

The first of these models, designated as MW-1, was an aluminum-alloy wing of 40-inch chord and semispan and was instrumented only with thermocouples. The test of this model was conducted to obtain skin and internal temperature variations with time. However, the aerodynamic heating and loading caused the model to flutter and fail near the end of the test. The results of the test of model MW-1 are presented in reference 1.

Subsequent models were similar to model MW-1 in design, but had 20-inch chords and semispans with the exception of MW-1-(2), a duplicate of MW-1, which had more thermocouple instrumentation than MW-1 and also had some strain-gage and pressure instrumentation. The 20-inch models differed in internal structure, skin thickness, and material. The results reported thus far on tests of these models can be found in references 2 to 8.

This paper presents the results for five models tested at $2^{\circ}$ angle of attack and at a Mach number of 2 with sea-level static temperature and pressure. These models, designated as MW-2-(4), MW-4(3), MW-16, MW-17, and MW-18, varied only in the type and amount of chordwise stiffening. Model temperatures and strains were measured and high-speed motion pictures were taken during all tests.

## SYMBOLS

| | |
|---|---|
| $a$ | speed of sound, fps |
| $l$ | distance along model chord from leading edge, ft |
| $M$ | Mach number |
| $p$ | pressure, psia |
| $q$ | dynamic pressure, $\frac{1}{2}\rho V^2$, psi |

[redacted]

R Reynolds number per foot, $\frac{\rho V l}{\mu}$

t time from start of air flow, sec

T temperature, $^{\circ}F$

V velocity of air, fps

$\alpha$ angle of attack, deg

$\mu$ absolute viscosity of air, slugs/ft-sec

$\rho$ density of air, slugs/cu ft

Subscripts:

aw adiabatic wall

o initial conditions

t tunnel stagnation conditions

$\infty$ free-stream conditions

## MODELS AND TESTS

### Model Construction

All the models in the group reported in this paper were of the same exterior configuration (20-inch chord and semispan and 5-percent-thick symmetrical circular-arc airfoil) and all were fabricated of 2024-T3 aluminum alloy. All models had solid leading and trailing edges and six 0.025-inch-thick formed, spanwise stiffeners and 0.064-inch-thick skins. The models were also identical in the design of the root section, with a solid root bulkhead and doubler plates to strengthen the root connection. Figure 1 shows the construction details of the models. Section AA shows details of the tip bulkheads, and section BB (fig. 1(a)) shows the root construction and attachment to the model mounting support.

The only difference in the design of the models was the type and amount of chordwise stiffening. Model MW-2-(4) had an 0.250-inch-thick solid tip bulkhead, whereas models MW-4-(3), MW-16, MW-17, and MW-18 had 0.025-inch-thick formed tip bulkheads. Also, models MW-2-(4) and MW-4(3) had no internal chordwise ribs whereas models MW-16, MW-17,

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and MW-18 had three, two, and one chordwise ribs, respectively. These ribs had the same dimensions as the tip bulkheads of models MW-4-(3), MW-16, MW-17, and MW-18, but were discontinuous at the spar webs. (See fig. 1(c).)

After the models were assembled, they were painted with a thin coating of zinc chromate primer and striped with black lacquer to form a grid pattern which aided in studying the model behavior recorded by the motion-picture films.

## Model Instrumentation

Instrumentation consisted of thermocouples and wire strain gages installed at the locations noted in figure 2. Figure 3 shows the strain-gage and thermocouple instrumentation and the internal structure of model MW-16 prior to final assembly. Much of the instrumentation for models MW-16, MW-17, and MW-18 (fig. 2) was inoperative for the tests reported herein because of damage incurred in previous tests.

Iron-constantan thermocouples were installed in the skins and stiffeners by forming a common bead on one end of the thermocouple lead wires and peening the bead into a hole drilled to the midplane of the material at the desired location. Thermocouples located in the interior of the solid leading- and trailing-edge sections (MW-16) were installed by coating the hot-junction beads with cement and inserting the beads into small holes drilled into those sections.

The model strain gages were SR-4 type EBDF-7D temperature-compensated wire strain gages and were attached to the models with thermosetting cement. These gages are temperature-compensated to read approximately zero strain on unstressed 2024-T3 aluminum alloy at temperatures between 50° F and 250° F. A detailed explanation of the strain-gage installation technique and temperature compensation is discussed in reference 7.

## Accuracy of Data

The estimated probable errors in individual measurements of the model and tunnel instrumentation, and the corresponding time constants are presented in the following table:

[redacted]

| Item | Probable error | Time constant,[a] sec |
|---|---|---|
| Tunnel stagnation pressure . . . . . . | ±0.7 psi | 0.03 |
| Tunnel stagnation temperature . . . . | ±3° F | 0.12 |
| Model temperature . . . . . . . . . . | ±3° F | 0.03 |
| Model strain . . . . . . . . . . . . . . | ±150 μ in./in. | 0.02 |

[a]The time constant is defined to be the time required for a recorded value to reach 63 percent of a step-function input value. The determination of the time constant is independent of the probable error.

Errors that result from the hot-junction thermocouple installation have not been evaluated and are not included in the probable error, but these errors are believed to be small. These hot-junction errors can result from variations in the contact pressure between the thermocouple bead and the model skin when the model skin is vibrating, or in the case of the thermocouples in the leading and trailing edges of model MW-16, the errors can result from the insulating effect of the cement used in the installation.

## Vibration Nodal Patterns and Frequencies

Prior to the aerodynamic tests, the models were subjected to vibration surveys to determine their natural nodal patterns and corresponding frequencies at room temperature. (Models MW-16, MW-17, and MW-18 were previously surveyed. See ref. 7.) An air-jet shaker was used to excite the models and the vibrations were received by a velocity pickup and circuited to a cathode-ray oscilloscope. The velocity pickup was moved over the surface of a model to determine the node lines; frequencies were measured by a Stroboconn frequency meter. Figure 4 shows the results of these surveys. The nodal patterns (fig. 4) are composites for all models; individual model node lines varied slightly.

Although the five models were outwardly identical, they were different structurally; therefore, their natural modes and frequencies might be expected to be dissimilar. The lightest model, MW-4-(3), which had a light tip bulkhead and no ribs, can be used as a basis of structural comparison since the remaining models varied either by having a heavier tip rib (MW-2-(4)) or by the addition of one, two, or three ribs (MW-18, MW-17, or MW-16). The heavier tip bulkhead of model MW-2-(4) (over that of model MW-4-(3)) resulted in no significant difference in either the nodal patterns or corresponding frequencies (except for pattern K of fig. 4); any additional stiffness near the tip of the wing was apparently offset dynamically by the added mass.

Since the two models without ribs responded similarly over the frequency range covered by this survey, another comparison can be made between the models without ribs and those having ribs. The lowest frequency of the first mode involving primarily chordwise distortion for the rib-stiffened models (nodal pattern I) was 450 cps, whereas, for the models with no ribs, the frequencies were less than 280 cps (nodal pattern C). The addition of ribs to the basic model design (MW-4-(3)) changed nodal pattern C from a mode involving primarily chordwise distortion to nodal pattern D, a mode involving primarily bending distortions. Also, over the frequency range of this survey, the models without ribs experienced more chordwise distortion modes than were experienced by the rib-stiffened models. Therefore, as expected, the models without chordwise ribs were considerably less resistant to chordwise distortions than were the rib-stiffened models. Moreover, the addition of one rib to the basic model design is sufficient to preclude natural modes involving primarily chordwise distortion in the frequency range below 450 cps.

The results shown for models MW-16, MW-17, and MW-18 differ only slightly from previous results for these models reported in reference 7. In general, the modal frequencies reported herein are lower than those reported in reference 7. These lower frequencies probably indicate a reduction in stiffness resulting from repeated testing of these models.

## Test Facility

The facility used for the aerodynamic tests of the multiweb wing models was the preflight jet of the NASA Wallops Station. This facility is a supersonic, blowdown jet which utilizes a heat accumulator for stagnation-temperature control. Models were tested in a free jet at a Mach number of 2 downstream of the exit of the 27- by 27-inch nozzle. This facility and its operation are discussed in the appendix of reference 2.

## Test Procedure

Model mounting.- The models were mounted root downward at an angle of attack of $2^{\circ}$ with the leading edge approximately 2 inches downstream of the nozzle exit plane. Figure 5 shows a typical model in test position at the exit of the 27- by 27-inch jet. (The two stagnation-temperature probes located to the rear of the model were not used for the tests discussed in this paper.) The angle of attack is noted as positive for clockwise rotation looking down on the tip of the model. The models were pivoted about a point $21\frac{1}{2}$ inches downstream of the leading edge. The angle of attack was measured between the exit plane of the jet and the tip chord line of the model.

An aerodynamic fence surrounded the models near the root so that only $19\frac{7}{8}$ inches of the total semispan of $24\frac{1}{8}$ inches were exposed to the supersonic airstream. The sharp leading edge of the aerodynamic fence was positioned 1/8 of an inch above the lower jet boundary to remove some of the cold boundary layer. (See fig. 2.)

<u>Supporting equipment</u>.- The sequencing of the supporting equipment required for any test was accomplished with a programing device. The photographic lighting, time-correlating device, cameras, data recorders, and also the opening of the pressure control valve were individually energized on signal from the programer. The temperature, pressure, and strain data were recorded on three 18-channel recording oscillographs.

In the tests, five motion-picture cameras were focused on the models from various positions to record the model behavior. Two of these cameras were run at a film speed of 110 frames per second throughout the test, a third was run at a film speed of 1,000 frames per second throughout the test, and each of the remaining two cameras was sequenced to record approximately half a test at 1,600 frames per second.

## Test Conditions

Test conditions were considered to exist when the tunnel stagnation pressure exceeded 100 psia - the pressure required to establish supersonic flow over the entire model. For the tests on each of the five models, the tunnel stagnation pressures are plotted in figure 6(a) and the stagnation temperatures in figure 6(b). The average test stagnation pressures and temperatures presented in table 1 were obtained by integration of the area under the stagnation pressure and temperature curves shown in figure 6 for the interval when the stagnation pressure exceeded 100 psia. The dashed lines shown on the curves represent the average values thus obtained for the time interval in which test conditions were considered to exist. Zero time in all tests was referenced on all data records to the initial disturbance of a static-pressure pickup located slightly upstream from the nozzle exit plane.

The time of initial failure for models MW-2-(4) and MW-4-(3) is shown in figure 6 by the intersection of the vertical line and the pressure or temperature curve.

Table 1 presents the average aerodynamic test conditions determined from the Mach number, the average stagnation temperature, and the average stagnation pressure for the five tests discussed herein. The values

[redacted]

for stagnation pressure and temperature shown in parentheses in table 1 for models MW-2-(4) and MW-4-(3) are the values that prevailed at the time of initial failure of these models.

## RESULTS AND DISCUSSION

### Model Temperatures

Temperature data.- The temperature data at 1-second intervals for the five model tests discussed in this paper are presented in table 2. The data indicate that all tests were of a transient nature and hence insufficient in length for the models to reach steady-state temperatures. The data also show the characteristic temperature variations exhibited in previous multiweb wing tests in this jet facility. These variations indicate that a spanwise temperature gradient in the jet results in higher temperatures near the tip and midspan than near the root. The data also show a characteristic chordwise decrease in skin temperature from leading to trailing edge at any given time, due to a decrease in aerodynamic heat transfer with chord length. The amount of temperature data obtained was limited because of the larger thermocouple fatality.

Skin-web temperature differences.- The skin and web temperatures for models MW-2-(4) and MW-4-(3) at 2 seconds of test time have been plotted in figure 7. The temperature data for models MW-16, MW-17, and MW-18 were not plotted because the models did not fail and, unlike models MW-2-(4) and MW-4-(3), the data were obtained from very dissimilar locations and after repeated previous tests.

Figure 7 shows the temperatures, expressed nondimensionally to allow direct comparison, at corresponding skin and web center-line locations for models MW-2-(4) and MW-4-(3). Although there is considerable scatter in the data, the differences between the temperatures at the web center lines and the model skin temperatures (at locations where there was essentially no conduction to the stiffeners) can be seen, in general, to be appreciably greater for model MW-4-(3) than for model MW-2-(4); thus, it is reasonable to expect that the thermal stresses were also greater. (The actual thermal stress at a point is a function of the temperature difference between the weighted average temperature and the temperature of the point.)

The larger temperature differences for model MW-4-(3) might be attributed either to differences in the imposed test heating conditions or to normal fabrication differences in the models, such as differences in the joints. However, since the aerodynamic heat-transfer coefficients should have been almost identical, and since there was also very

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little difference in the heat-transfer forcing function $T_{aw} - T$ for the two wings, the external transfer of heat to the models cannot account for the temperature differences. Hence, these differences must be largely due to differences in the thermal conductivity of the joints between the skins and the web flanges. (For a study of the influence of joint thermal conductivity on temperature distribution and resulting thermal stresses in similar structural components, see ref. 9.)

## Model Strains

The model strain data at 1-second intervals are shown in table 3 exactly as they were reduced from the oscillograph records, i.e., without any temperature corrections. Where data are not given in this table, either the strain gage was inoperative or large oscillations in the oscillograph record prevented reading the data.

All the strain gages installed in models MW-2-(4) and MW-4-(3) except gages 8 and 9 were intended to be used to record the frequency of vibrations and allow phasing of any chordwise distortions; gages 8 and 9 were intended to yield strain histories in bending about the root. The results shown in table 3 for these two models serve only to show the relative magnitude of the recorded strains in the area of the gages. Although the gages experienced high-amplitude vibrations at frequencies above the flat frequencies of the galvanometers, the phasing analysis is believed to be reliable because the vibrations were nearly equal in frequency and the attenuation in the signals from the gages should have been approximately the same.

The strain gages installed in models MW-16, MW-17, and MW-18 were also intended primarily to record frequency histories; in addition, a few gages were mounted in pairs at right angles to one another to yield biaxial strains so that the local stresses could be approximated at these locations. Also, some single gages were installed on the skin opposite the right-angled pairs and alined with one of the gages to indicate the corresponding strains in the opposite skin. Although 12 pairs of gages were installed in models MW-16, MW-17, and MW-18 to record biaxial strains, only four pairs were operative in these tests (one pair in MW-16, one pair in MW-17, and two pairs in MW-18). The strain gages in models MW-16, MW-17, and MW-18 experienced low-frequency, low-amplitude vibrations; thus, the recorded strains should have been influenced only to a minor degree by such factors as attenuation. However, determination from the strain-gage histories of the true strains experienced by the models is subject to several sources of error, such as temperature compensation for zero drift of the gages. Because of this and other sources of error and because only four pairs of

[redacted]

perpendicular gages were operative, no experimental stress data are presented. Similarly, no calculated stress data are included. Stresses derived from the limited biaxial strain data were generally in fair agreement with stresses calculated by using approximate methods for determining thermal stresses and stresses due to loads.

## Model Behavior

All five models were tested under fairly similar conditions, as can be seen from table 1. However, as might be expected from the known physical differences in the models (fig. 1), the wings behaved somewhat differently. Models MW-2-(4) and MW-4-(3), without any internal chordwise stiffening, failed, whereas the three models with internal chordwise ribs did not. A brief summary of the significant events which occurred during the tests is given in table 4, and these events are discussed in the following sections. One occurrence, common to all these tests, was that exhibited during the starting phase of the jet wherein the models were subjected to random pressure distributions and reacted by undergoing large bending deflections coupled with some smaller torsional deflections. Because of these disturbances and similar disturbances which occur during shutdown, repeated testing (as, for example, the previous tests of models MW-16, MW-17, and MW-18) could result in damage to the models and to instrumentation; however, although much of the original instrumentation in these models was inoperative, no damage to the model structure was evident prior to the tests. The behavior of all models and the times of the various events were obtained by correlating the strain-gage data with the high-speed motion pictures.

A motion-picture film supplement has been prepared of the tests on models MW-2-(4) and MW-4-(3) and is available on loan. A request card form and a description of the film will be found at the back of this paper, on the page immediately preceding the abstract and index pages.

Model MW-2-(4).- As indicated in table 4, model MW-2-(4) began to flutter at 1.77 seconds, just after the desired test conditions had been established. The flutter occurred at a frequency of 480 to 500 cps, was of small amplitude with five spanwise node lines across the chord, and included only slight distortion of the tip bulkhead. This initial flutter mode of $2\frac{1}{2}$ waves was different from the $1\frac{1}{2}$-wave flutter mode observed before failure on similar models in this test series tested at 0° angle of attack (ref. 5). Tests of model MW-2-(2) at angles of attack of -2° and 2° (runs 4 and 6 of ref. 4) revealed a low-amplitude flutter at 360 to 400 cps. Although an accurate description of the flutter mode cannot be determined for model MW-2-(2) from the high-speed motion pictures because of the small amplitude of vibrations and

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lack of clarity of the films, the flutter mode appears to be similar to the initial flutter mode described herein for model MW-2-(4).

As in similar tests where failure due to flutter had occurred, the amplitudes increased appreciably before failure, especially near the trailing edge. At 5.01 seconds, failure occurred when the rivets connecting the fifth web (from the leading edge) and the skin failed. Shortly thereafter the mode changed to the more usual $1\frac{1}{2}$ waves across the chord, the amplitudes increased considerably, and the frequency dropped to about 200 cps. At 5.79 seconds, the wing tore away completely from its root attachment.

Model MW-4-(3).- The behavior of model MW-4-(3) was quite similar to that of model MW-2-(4) until failure occurred, except that flutter began slightly sooner, at 1.50 seconds (table 4). However, this wing experienced a static bending type of failure at 2.56 seconds by collapse at the root while undergoing flutter at approximately 480 cps.

Models MW-16, MW-17, and MW-18.- Models MW-16, MW-17, and MW-18 behaved similarly during their tests in that the models experienced very low-amplitude vibrations with frequencies of from 45 to 70 cps during the period of test conditions. All three models survived the tests with no apparent physical damage. Thus, since essentially the same aerodynamic loading and heating were imposed on all five models, the additional chordwise stiffness obtained by adding one, two, or three internal chordwise ribs apparently sufficed to prevent flutter and subsequent failure.

Failures of models MW-2-(4) and MW-4-(3).- One apparent structural difference between models MW-2-(4) and MW-4-(3) was in the tip bulkheads; model MW-2-(4) had a solid 1/4-inch-thick tip bulkhead, whereas model MW-4-(3) had a light, formed bulkhead 0.025 inch thick. The effect of this difference in chordwise bending stiffness at the tip may have resulted in the slightly earlier flutter of model MW-4-(3). A second difference was in the amount of built-in twist (less than $0.5^{\circ}$ for either model) which raised the aerodynamic pressure loading on model MW-2-(4) very slightly over that on model MW-4-(3). A third difference was in the thermal conductivity of the joints of the two models; as seen from figure 7, this resulted in larger skin-web temperature differences for model MW-4-(3), and consequently in larger thermal stresses.

Both models began to flutter after test conditions had been established (i.e., after the stagnation pressure exceeded 100 psia) and their flutter behavior was very similar. However, the onset of flutter occurred slightly earlier for MW-4-(3) than for MW-2-(4), and the time and manner of failure of these models were different. These differences in the failures probably were a result of thermal stresses induced by

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aerodynamic heating. Because of the lower joint conductivity of model MW-4-(3), the increase of thermal stress with time was more rapid for this model than for model MW-2-(4). A state of critical stress was apparently reached in model MW-4-(3) at 2.56 seconds, at which time the combined stresses due to aerodynamic loading and aerodynamic heating caused skin buckling and collapse. However, for model MW-2-(4), the increase in thermal stress was considerably more gradual and the effect was less severe.

## SUMMARY OF RESULTS

Aerodynamic tests were performed on five multiweb wing models at $2^{\circ}$ angle of attack in a Mach number 2 free jet under simulated supersonic flight conditions at sea-level static temperature and pressure. Model temperatures and strains were measured and high-speed motion-picture cameras were used to photograph the model behavior. Because of uncertainties in converting the strain data to stresses, the strain-gage histories were used only to aid in reconstructing the behavior of the models.

The model temperature data revealed that all tests were of a transient nature. The amount of temperature data obtained was limited because of the large thermocouple fatality.

Model MW-2-(4) fluttered and failed partway through its test. Model MW-4-(3) experienced a static bending type of failure at the root while undergoing flutter.

The flutter mode of $2\frac{1}{2}$ waves exhibited by models MW-2-(4) and MW-4-(3) in these tests (at $2^{\circ}$ angle of attack) was different from the $1\frac{1}{2}$-wave flutter mode exhibited by similar models in this test series at $0^{\circ}$ angle of attack. However, previous tests of model MW-2-(2) made at an angle of attack of $-2^{\circ}$ and $2^{\circ}$ (NACA RM L57H19) revealed a low-amplitude flutter mode which appears to be similar to the $2\frac{1}{2}$-wave flutter mode discussed herein for models MW-2-(4) and MW-4-(3).

Models MW-16, MW-17, and MW-18, which had internal chordwise ribs between the root and tip bulkhead, survived the tests without apparent structural damage.

The tests of the five models indicate that small differences in model construction appreciably affect the model behavior and that the addition of one or more chordwise ribs apparently stiffens the design

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sufficiently to prevent chordwise distortions, flutter, and subsequent failures similar to those experienced by models MW-2-(4) and MW-4-(3) under these test conditions.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Field, Va., August 26, 1959.

[redacted]

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TABLE 1

AERODYNAMIC TEST CONDITIONS

$[\alpha = 2^{\circ};\ M = 1.99]$

| Test: Model | Test: Run | Stagnation pressure, $p_t$, psia (a) | Stagnation temperature, $T_t$, $^{\circ}F$ (a) | Free-stream static pressure, $p_\infty$, psia (a) | Free-stream dynamic pressure, $q_\infty$, psi | Free-stream temperature, $T_\infty$, $^{\circ}F$ | Free-stream velocity, $V_\infty$, fps | Free-stream density, $\rho_\infty$, slugs/cu ft | Speed of sound, a, fps | Reynolds number per foot, R |
|---|---|---|---|---|---|---|---|---|---|---|
| MW-2-(4) | 1 | 117.8 (114.3) | 558 (551) | 14.95 | 41.44 | 104 | 2,314 | $2.22 \times 10^{-3}$ | 1,163 | $12.87 \times 10^{6}$ |
| MW-4-(3) | 1 | 117.2 (116.8) | 535 (531) | 15.00 | 41.58 | 91 | 2,288 | 2.28 | 1,150 | 13.30 |
| MW-16 | 6 | 113.7 | 574 | 14.76 | 40.91 | 117 | 2,342 | 2.15 | 1,177 | 12.39 |
| MW-17 | 3 | 114.0 | 540 | 14.80 | 41.03 | 98 | 2,304 | 2.23 | 1,158 | 12.95 |
| MW-18 | 3 | 112.5 | 524 | 14.60 | 40.47 | 89 | 2,285 | 2.23 | 1,148 | 13.04 |

[a] Values in parentheses are those that prevailed at time of failure of model.

[redacted]

[redacted]

TABLE 2

MODEL TEMPERATURES

| Time, sec | Temperature, °F at thermocouple[a] - | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 33 | 34 | 35 |
| Model MW-2-(4) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 72 | 73 | 71 | 72 | 74 | 71 | 73 | 74 | 72 | 71 | 71 | 72 | 73 | 71 | 74 | 70 | 74 | 74 | 71 | 72 | 71 | | | | | | | | | | | |
| 1 | 89 | 121 | 76 | 113 | 121 | 75 | 104 | 117 | 107 | 95 | 73 | 115 | 112 | 73 | 114 | 75 | 114 | 112 | 76 | 112 | 85 | | | | | | | | | | | |
| 2 | 145 | 213 | | 172 | 198 | 125 | 139 | | 178 | 141 | 114 | | 180 | 113 | | 111 | 200 | | 171 | | | | | | | | | | | | | |
| 3 | | | | 205 | | | 169 | | | 206 | | | 254 | | | 168 | | | | | | | | | | | | | | | | |
| 4 | | | | 244 | | | 209 | | | 250 | | | 294 | | | 229 | | | | | | | | | | | | | | | | |
| 5 | | | | 293 | | | 253 | | | | | | | | | 221 | | | | | | | | | | | | | | | | |
| Model MW-4-(3) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 52 | 51 | 50 | | 54 | 54 | 54 | | 50 | 54 | 53 | 53 | 57 | 51 | 54 | 51 | 53 | 57 | 49 | 52 | 51 | | | | | | | | | | | |
| 1 | 67 | 101 | 58 | | 101 | 57 | 92 | | 88 | 78 | 56 | 98 | 97 | 55 | 95 | 57 | 92 | 94 | 56 | 93 | 62 | | | | | | | | | | | |
| 2 | 113 | 205 | 74 | | 171 | 79 | 164 | | 144 | 126 | 73 | 170 | 160 | 73 | 168 | 76 | 166 | 166 | 100 | 165 | 101 | | | | | | | | | | | |
| Model MW-16 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 80 | 79 | | 83 | 85 | | | | | | | | | | 79 | 82 | 84 | 79 | 76 | 77 | 76 | | | | | 78 | 74 | 78 | 80 | | | |
| 1 | 103 | 89 | | 130 | 111 | | | | | | | | | | 114 | 110 | 112 | 81 | 110 | 79 | 79 | | | | | 86 | 88 | 100 | 144 | | | |
| 2 | 170 | 129 | | 219 | 162 | | | | | | | | | | 179 | 157 | 152 | 90 | 178 | 92 | 91 | | | | | 118 | 135 | 159 | 267 | | | |
| 3 | 249 | 190 | | 301 | 216 | | | | | | | | | | 235 | 207 | 199 | 117 | 242 | 115 | 116 | | | | | 156 | 175 | 202 | 302 | | | |
| 4 | 310 | 248 | | 356 | 257 | | | | | | | | | | 277 | 244 | 232 | 147 | 288 | 146 | 146 | | | | | 189 | 209 | 236 | 332 | | | |
| 5 | 356 | 299 | | 394 | 287 | | | | | | | | | | 311 | 271 | 259 | 175 | 327 | 178 | 179 | | | | | 221 | 239 | 265 | 357 | | | |
| 6 | 383 | 340 | | 423 | 309 | | | | | | | | | | 339 | 293 | 279 | 201 | 358 | 209 | 211 | | | | | 249 | 266 | 290 | 375 | | | |
| 7 | 414 | 375 | | 442 | 324 | | | | | | | | | | 362 | 310 | 296 | 227 | 381 | 238 | 240 | | | | | 275 | 290 | 313 | 388 | | | |
| 8 | 436 | 403 | | 459 | 339 | | | | | | | | | | 381 | 324 | 309 | 249 | 400 | 265 | 268 | | | | | 296 | 313 | 332 | 399 | | | |
| 9 | 451 | 424 | | 469 | 348 | | | | | | | | | | 396 | 334 | 319 | 267 | 416 | 289 | 293 | | | | | 318 | 332 | 349 | 406 | | | |
| 10 | 460 | 441 | | 477 | 356 | | | | | | | | | | 407 | 342 | 327 | 283 | 428 | 310 | 315 | | | | | 336 | 349 | 364 | 412 | | | |
| 11 | 469 | 453 | | 483 | 363 | | | | | | | | | | 417 | 349 | 333 | 296 | 437 | 329 | 334 | | | | | 354 | 365 | 378 | 416 | | | |
| 12 | 475 | 464 | | 487 | 366 | | | | | | | | | | 424 | 354 | 336 | 308 | 442 | 344 | 350 | | | | | 369 | 380 | 391 | 417 | | | |
| 13 | 475 | 472 | | 488 | 365 | | | | | | | | | | 431 | 354 | 326 | 318 | 445 | 360 | 366 | | | | | 386 | 397 | 408 | 422 | | | |
| 14 | | 477 | | 487 | 356 | | | | | | | | | | 418 | 352 | 323 | 325 | 443 | 373 | 381 | | | | | 395 | 403 | 408 | 390 | | | |
| 15 | | 477 | | 482 | 356 | | | | | | | | | | 417 | 350 | 319 | 333 | 441 | 383 | 388 | | | | | 398 | 403 | 407 | 395 | | | |
| Model MW-17 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | 70 | 75 | 73 | | 74 | 73 | 74 | | | 64 | | 73 | 70 | | | 65 | 64 | 66 | 64 | | | 74 | 78 | | | 74 | 73 | | | 64 | 63 | 70 |
| 1 | 113 | 109 | 77 | | 105 | 71 | 103 | | | 67 | | 74 | 106 | | | 103 | 99 | 105 | 101 | | | 104 | 105 | | | 77 | 100 | | | 95 | 93 | 96 |
| 2 | 203 | 162 | 93 | | 155 | 87 | 153 | | | 83 | | 83 | 179 | | | 165 | 158 | 175 | 164 | | | 144 | 137 | | | 85 | 142 | | | 168 | 159 | 139 |
| 3 | 281 | 205 | 141 | | 204 | 115 | 198 | | | 114 | | 104 | 240 | | | 223 | 215 | 240 | 228 | | | 184 | 178 | | | 103 | 181 | | | 214 | 201 | 175 |
| 4 | 334 | 242 | 178 | | 238 | 150 | 231 | | | 155 | | 131 | 285 | | | 267 | 259 | 288 | 276 | | | 215 | 210 | | | 126 | 211 | | | 229 | 234 | 202 |
| 5 | 362 | 270 | 206 | | 263 | 181 | 260 | | | 196 | | 157 | 320 | | | 304 | 293 | 323 | 312 | | | 239 | 233 | | | 151 | 234 | | | 241 | 262 | 221 |
| 6 | 389 | 297 | 233 | | 284 | 205 | 277 | | | 235 | | 183 | 350 | | | 330 | 322 | 353 | 345 | | | 256 | 252 | | | 175 | 253 | | | 310 | 288 | 241 |
| 7 | 405 | 319 | 254 | | 300 | 230 | 294 | | | 272 | | 206 | 374 | | | 355 | 348 | 377 | 370 | | | 273 | 269 | | | 198 | 269 | | | 332 | 310 | 255 |
| 8 | 433 | 321 | 272 | | 313 | 250 | 307 | | | 303 | | 225 | 394 | | | 375 | 367 | 396 | 390 | | | 285 | 282 | | | 217 | 283 | | | 353 | 329 | 267 |
| 9 | 445 | 331 | 288 | | 323 | 268 | 317 | | | 331 | | 243 | 408 | | | 392 | 385 | 413 | 406 | | | 295 | 293 | | | 234 | 293 | | | 370 | 347 | 278 |
| 10 | 454 | 338 | 301 | | 330 | 283 | 325 | | | 355 | | 259 | 421 | | | 405 | 400 | 425 | 420 | | | 304 | 301 | | | 249 | 301 | | | 385 | 360 | 286 |
| 11 | 461 | 343 | 309 | | 335 | 294 | 331 | | | 374 | | 273 | 430 | | | 417 | 411 | 436 | 431 | | | 311 | 308 | | | 261 | 307 | | | 395 | 372 | 292 |
| 12 | 463 | 346 | 318 | | 339 | 303 | 335 | | | 389 | | 284 | 437 | | | 425 | 419 | 442 | 439 | | | 318 | 309 | | | 272 | 314 | | | 406 | 385 | 298 |
| 13 | 465 | 346 | 326 | | 338 | 309 | 333 | | | 401 | | 291 | 443 | | | 429 | 423 | 444 | 442 | | | 316 | 295 | | | 280 | 314 | | | 418 | 399 | 298 |
| 14 | | 339 | 323 | | 332 | 309 | 329 | | | 412 | | 295 | 433 | | | 427 | 423 | 443 | 444 | | | 313 | 294 | | | 284 | 314 | | | 406 | 384 | 296 |
| 15 | | 335 | 317 | | 329 | 311 | 327 | | | 414 | | 302 | 431 | | | 425 | 422 | 441 | 442 | | | 312 | 294 | | | 285 | 313 | | | 406 | 386 | 293 |
| Model MW-18 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 0 | | 67 | | | | | | | 65 | 64 | 70 | 66 | 62 | 64 | | 70 | 68 | | | | 65 | | 56 | 68 | 70 | 73 | 63 | 67 | | | 65 | 69 |
| 1 | | 95 | | | | | | | 100 | 99 | 99 | 88 | 71 | 69 | | 71 | 102 | | | | 103 | | 91 | 97 | 95 | 94 | 71 | 67 | | | 96 | 93 |
| 2 | | 136 | | | | | | | 164 | 156 | 139 | 121 | 81 | 78 | | 78 | 168 | | | | 168 | | 155 | 147 | 133 | 125 | 76 | 73 | | | 161 | 131 |
| 3 | | 176 | | | | | | | 226 | 208 | 182 | 168 | 99 | 100 | | 92 | 224 | | | | 229 | | 214 | 193 | 170 | 158 | 88 | 88 | | | 200 | 164 |
| 4 | | 204 | | | | | | | 277 | 252 | 215 | 217 | 120 | 131 | | 116 | 268 | | | | 277 | | 260 | 234 | 203 | 187 | 103 | 108 | | | 234 | 189 |
| 5 | | 226 | | | | | | | 317 | 285 | 242 | 258 | 145 | 167 | | 140 | 307 | | | | 314 | | 297 | 266 | 229 | 211 | 124 | [illegible] | | | 264 | 211 |
| 6 | | 242 | | | | | | | 347 | 311 | 262 | 293 | 171 | 201 | | 163 | 336 | | | | 345 | | 326 | 291 | 248 | 230 | 145 | 150 | | | 289 | 227 |
| 7 | | 254 | | | | | | | 371 | 332 | 277 | 323 | 198 | 235 | | 186 | 359 | | | | 368 | | 349 | 313 | 263 | 246 | 170 | 170 | | | 313 | 241 |
| 8 | | 263 | | | | | | | 391 | 349 | 289 | 347 | 226 | 269 | | 205 | 378 | | | | 387 | | 369 | 330 | 276 | 257 | 195 | 188 | | | 331 | 254 |
| 9 | | 271 | | | | | | | 407 | 362 | 300 | 368 | 251 | 296 | | 222 | 393 | | | | 403 | | 384 | 344 | 286 | 268 | 219 | 205 | | | 348 | 263 |
| 10 | | 277 | | | | | | | 418 | 372 | 306 | 382 | 275 | 321 | | 237 | 404 | | | | 415 | | 394 | 355 | 294 | 277 | 243 | 221 | | | 362 | 272 |
| 11 | | 283 | | | | | | | 427 | 381 | 312 | 393 | 296 | 341 | | 248 | 414 | | | | 424 | | 402 | 363 | 300 | 280 | 262 | 234 | | | 374 | 279 |
| 12 | | 284 | | | | | | | 433 | 385 | 315 | 403 | 314 | 358 | | 259 | 422 | | | | 430 | | 409 | 368 | 303 | 272 | 281 | 245 | | | 390 | 282 |
| 13 | | 278 | | | | | | | 438 | 386 | 308 | 419 | 336 | 377 | | 264 | 428 | | | | 435 | | 415 | 373 | 299 | 266 | 306 | 253 | | | 398 | 278 |
| 14 | | 278 | | | | | | | 439 | 387 | 310 | 419 | 367 | 380 | | 268 | 419 | | | | 435 | | 413 | 372 | 301 | 270 | 339 | 260 | | | 386 | 279 |
| 15 | | 276 | | | | | | | 438 | 385 | 308 | 418 | 367 | 388 | | 271 | 417 | | | | 433 | | 412 | 373 | 299 | 268 | 340 | 266 | | | 385 | 275 |

[a]Where data for a particular thermocouple are not given, thermocouple was not in proper working condition at time of test; where data are listed for only part of test, values beyond those given were considered unreliable.

[redacted]

[redacted]



TABLE 3

MODEL STRAIN HISTORIES

| Time, sec | Strain, μ in./in., at strain gage[a] – | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 16 | 17 | 20 | 21 |
| Model MW-2-(4) | | | | | | | | | | | | | | | | | | |
| 0 | 3 | 4 | -2 | -9 | 7 | -10 | 0 | 5 | 0 | 5 | 8 | 2 | -2 | 4 | | | | |
| 1 | 567 | 116 | 476 | 52 | 22 | -67 | -29 | -661 | 877 | -96 | -102 | -169 | -191 | -154 | | | | |
| 2 | 409 | 116 | 558 | 59 | 225 | -62 | -355 | -952 | 1,705 | -84 | | -555 | 801 | 198 | | | | |
| 3 | | | 594 | 182 | 618 | | 931 | -726 | 1,686 | 884 | | | | | | | | |
| 4 | | | 626 | 196 | 789 | | 880 | -290 | 1,703 | | | | | | | | | |
| 5 | | | 536 | 140 | 813 | | 540 | | | | | | | | | | | |
| Model MW-4-(3) | | | | | | | | | | | | | | | | | | |
| 0 | -7 | -15 | 0 | -4 | -3 | -53 | -41 | 0 | 17 | -14 | -7 | -2 | 2 | -7 | | | | |
| 1 | 707 | 67 | 529 | 81 | 78 | -53 | -57 | -634 | 894 | -75 | -72 | -122 | -166 | -93 | | | | |
| 2 | 714 | 53 | 636 | 171 | 315 | -53 | -623 | 309 | 1,995 | -113 | 234 | 275 | 266 | 123 | | | | |
| Model MW-16 | | | | | | | | | | | | | | | | | | |
| 0 | | | | -2 | | 15 | | | 9 | | | | | | 9 | | | |
| 1 | | | | 199 | | 235 | | | 228 | | | | | | 65 | | | |
| 2 | | | | 759 | | 430 | | | 1,469 | | | | | | 104 | | | |
| 3 | | | | 758 | | 590 | | | 1,488 | | | | | | 154 | | | |
| 4 | | | | 660 | | 602 | | | 1,313 | | | | | | 160 | | | |
| 5 | | | | 616 | | 500 | | | 1,211 | | | | | | 140 | | | |
| 6 | | | | 537 | | 368 | | | 1,103 | | | | | | 115 | | | |
| 7 | | | | 482 | | 225 | | | 1,031 | | | | | | 78 | | | |
| 8 | | | | 436 | | 94 | | | | | | | | | 39 | | | |
| 9 | | | | 395 | | -38 | | | 1,470 | | | | | | -20 | | | |
| 10 | | | | 431 | | -184 | | | 1,395 | | | | | | -60 | | | |
| 11 | | | | 359 | | -223 | | | 1,242 | | | | | | -99 | | | |
| 12 | | | | 253 | | -288 | | | 1,089 | | | | | | -89 | | | |
| 13 | | | | 121 | | -355 | | | 916 | | | | | | -114 | | | |
| 14 | | | | 31 | | -418 | | | 696 | | | | | | -45 | | | |
| 15 | | | | -31 | | -466 | | | 587 | | | | | | -97 | | | |
| Model MW-17 | | | | | | | | | | | | | | | | | | |
| 0 | -5 | | -22 | 19 | | -27 | | 14 | 2 | -9 | 12 | 27 | | | | 10 | | |
| 1 | 361 | | | 194 | | 189 | | -38 | -24 | -113 | 118 | -36 | | | | -10 | | |
| 2 | 501 | | 81 | 457 | | 21 | | -45 | 323 | -376 | 1,267 | -1,044 | | | | 153 | | |
| 3 | 530 | | 106 | 603 | | 21 | | -104 | 251 | -480 | 1,288 | -1,102 | | | | 166 | | |
| 4 | 519 | | 141 | 641 | | 31 | | -139 | 222 | -570 | 1,278 | -1,112 | | | | 153 | | |
| 5 | 517 | | 183 | 611 | | 26 | | -138 | 236 | -646 | 1,271 | -1,120 | | | | 151 | | |
| 6 | 521 | | 277 | 562 | | -5 | | -145 | 252 | -692 | 1,262 | -1,132 | | | | 145 | | |
| 7 | 516 | | 179 | 507 | | -23 | | -86 | 345 | -727 | 1,265 | -1,136 | | | | 151 | | |
| 8 | 569 | | 107 | 453 | | -15 | | -25 | 381 | -732 | 1,290 | -1,154 | | | | 164 | | |
| 9 | 579 | | 79 | 400 | | -18 | | -4 | 400 | -754 | 1,231 | -1,125 | | | | 164 | | |
| 10 | 580 | | 70 | 345 | | 5 | | 21 | 414 | -776 | 1,191 | -1,088 | | | | 184 | | |
| 11 | 526 | | 48 | 293 | | 65 | | 21 | 394 | -811 | 1,018 | -941 | | | | 201 | | |
| 12 | 495 | | 19 | 225 | | 26 | | 25 | 341 | -776 | 805 | -751 | | | | 189 | | |
| 13 | 608 | | | 113 | | -65 | | 289 | 354 | -767 | 497 | -381 | | | | 240 | | |
| 14 | 352 | | | 47 | | 40 | | 186 | -18 | -615 | -54 | 32 | | | | 270 | | |
| 15 | 335 | | -16 | 21 | | -3 | | 152 | 118 | -603 | -133 | 0 | | | | 255 | | |
| Model MW-18 | | | | | | | | | | | | | | | | | | |
| 0 | | | | 29 | | [illegible] | | | | -17 | 10 | 0 | | | | | 4 | 16 |
| 1 | | | | 133 | | 283 | | | | -85 | 299 | -38 | | | | | -2 | 89 |
| 2 | | | | 419 | | 524 | | | | -358 | 1,045 | -468 | | | | | -173 | 344 |
| 3 | | | | 433 | | 685 | | | | -484 | 1,110 | -549 | | | | | -265 | 326 |
| 4 | | | | 476 | | 732 | | | | -573 | 1,200 | -472 | | | | | -353 | 342 |
| 5 | | | | 498 | | 727 | | | | -623 | 1,191 | -455 | | | | | -406 | 316 |
| 6 | | | | 520 | | 682 | | | | -688 | 1,203 | -510 | | | | | -440 | 323 |
| 7 | | | | 527 | | 604 | | | | -715 | 1,211 | -182 | | | | | -483 | 323 |
| 8 | | | | 541 | | 564 | | | | -738 | 1,227 | -182 | | | | | -511 | 324 |
| 9 | | | | 536 | | [illegible] | | | | -755 | 1,222 | -183 | | | | | -529 | 316 |
| 10 | | | | 513 | | 404 | | | | -812 | 1,152 | -176 | | | | | -542 | 248 |
| 11 | | | | 430 | | [illegible] | | | | -864 | 1,011 | -15 | | | | | -575 | 154 |
| 12 | | | | 279 | | 191 | | | | -753 | 825 | 334 | | | | | -558 | 118 |
| 13 | | | | 181 | | 43 | | | | -708 | 304 | 237 | | | | | -419 | -66 |
| 14 | | | | 10 | | -23 | | | | -678 | 221 | 111 | | | | | -358 | -45 |
| 15 | | | | 3 | | [illegible] | | | | -673 | 207 | 113 | | | | | -371 | -26 |

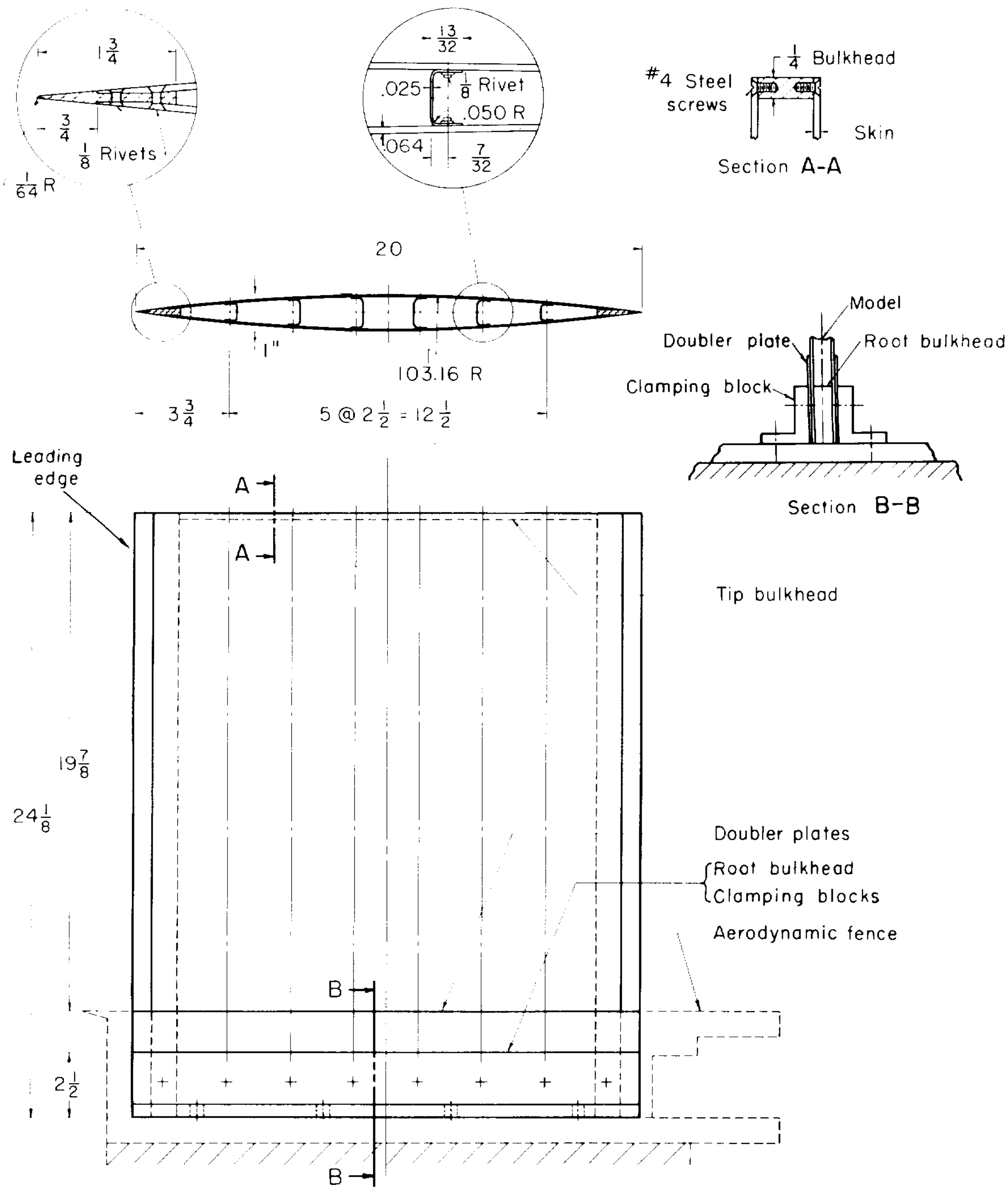
[a]Negative sign indicates compressive strain; when the strain gages recorded oscillating strains, the mean value is presented here; where data are not given, either the strain gage was inoperative or large oscillations in the oscillograph record prevented reading the data.

[redacted]

TABLE 4

SUMMARY OF MODEL BEHAVIOR

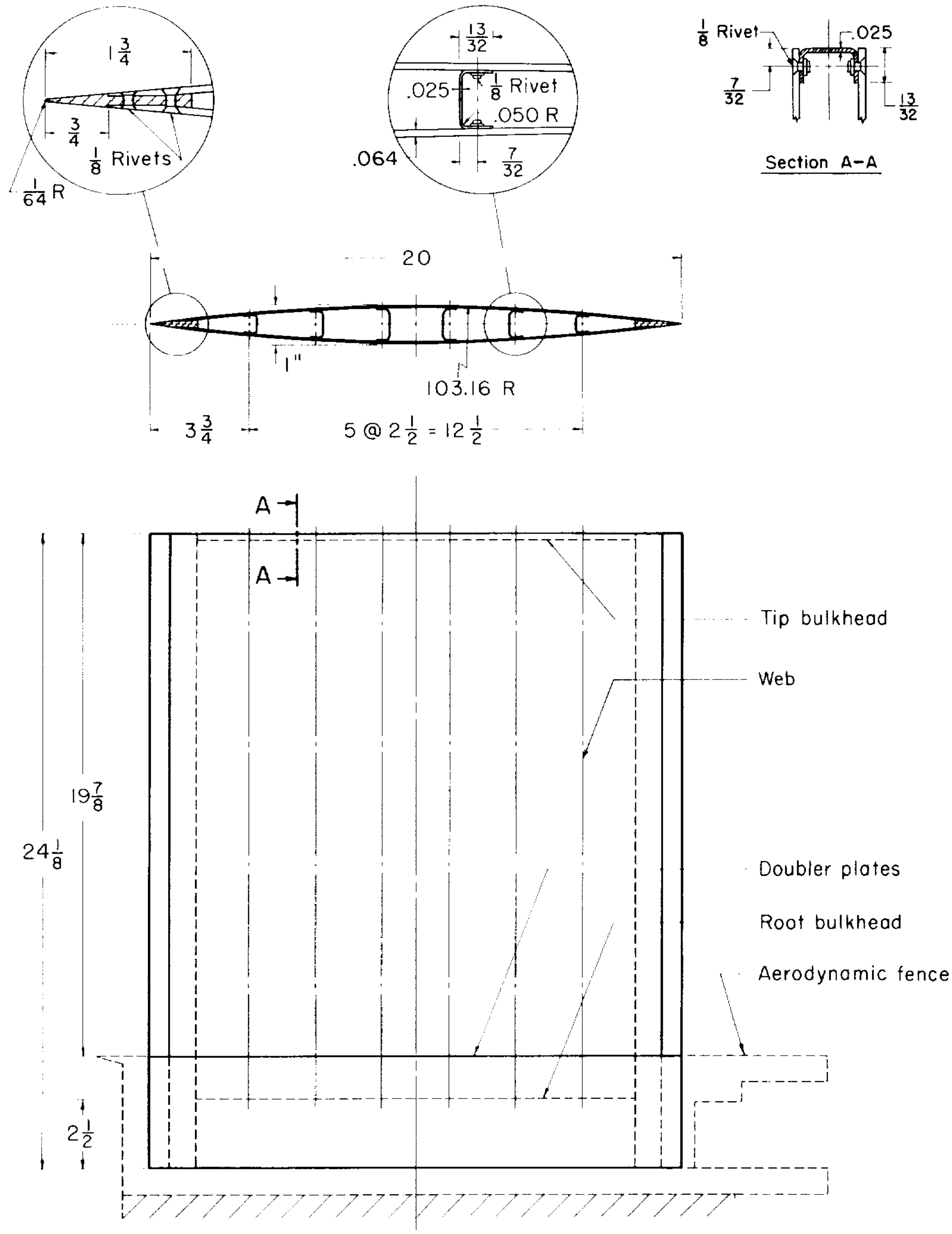
| Model | Time, sec | Event |
|---|---|---|
| MW-2-(4) | 0.26 to 0.99 | Random vibrations due to jet starting |
| | 0.99 to 1.72 | Model steady |
| | 1.77 | Small-amplitude, five-noded mode flutter at 480 to 500 cps |
| | 1.83 | Increase in flutter amplitude |
| | 4.98 | Marked increase in flutter amplitude near trailing edge |
| | 5.01 | First structural (rivet) failure; mode changed to $1\frac{1}{2}$ chordwise waves and frequency to 400 cps, then gradual decrease in frequency to 200 cps |
| | 5.79 | Wing tore away completely at root |
| MW-4-(3) | 0.26 to 0.99 | Random vibrations due to jet starting |
| | 0.99 to 1.50 | Model steady |
| | 1.50 to 2.54 | Small-amplitude, five-noded mode flutter at 480 to 500 cps |
| | 2.56 | Static bending type of failures at root |
| | 3.44 | Wing tore completely away at root |
| MW-16, MW-17, and MW-18 | 0.26 to 1.00 | Random vibrations due to jet starting |
| | Approximately 1.70 on | Models experienced very low-amplitude vibration at 45 to 70 cps |




(a) Model MW-2-(4).

Figure 1.- Dimensions of multiweb wings.

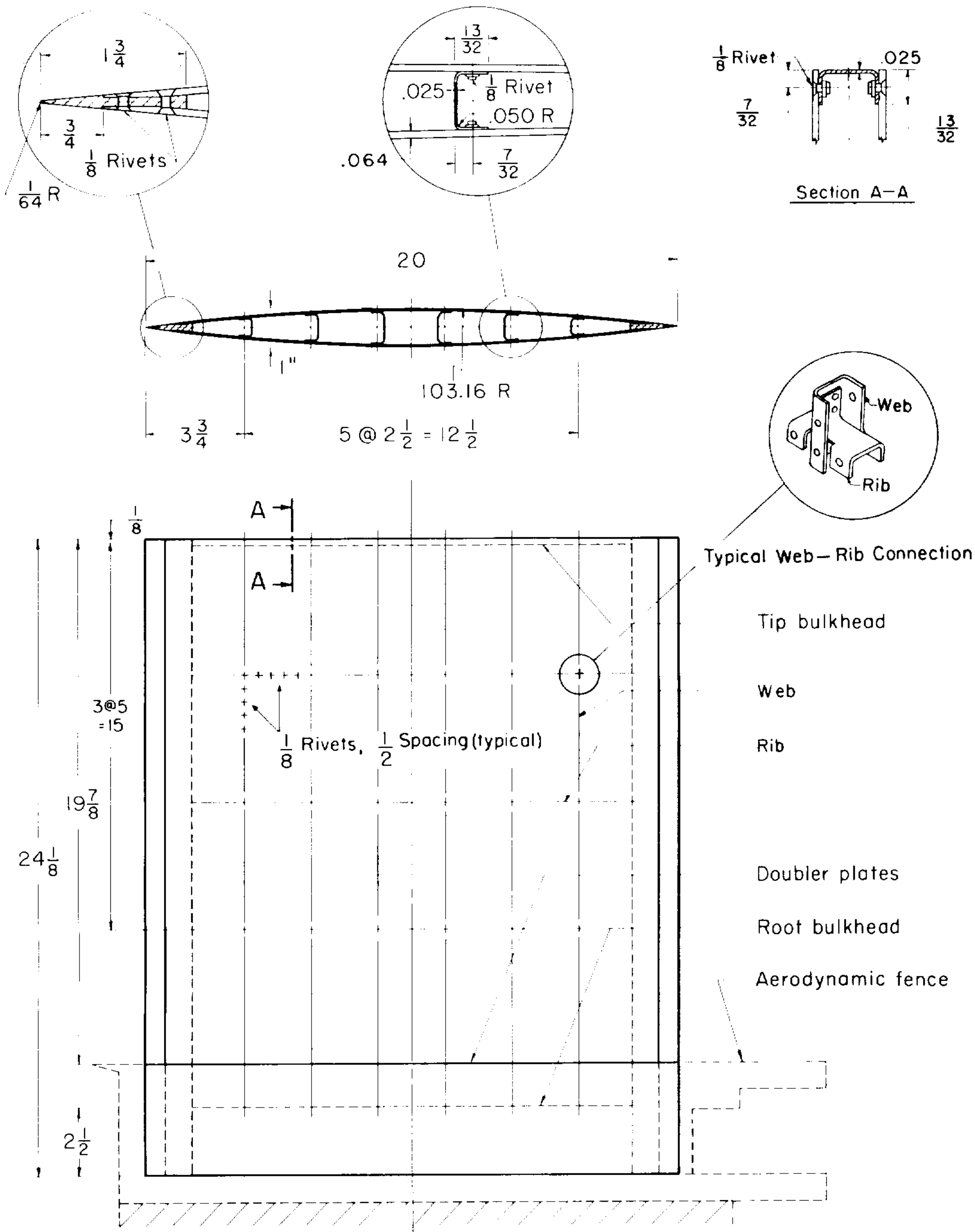
[redacted]




(b) Model MW-4-(3).

Figure 1.- Continued.

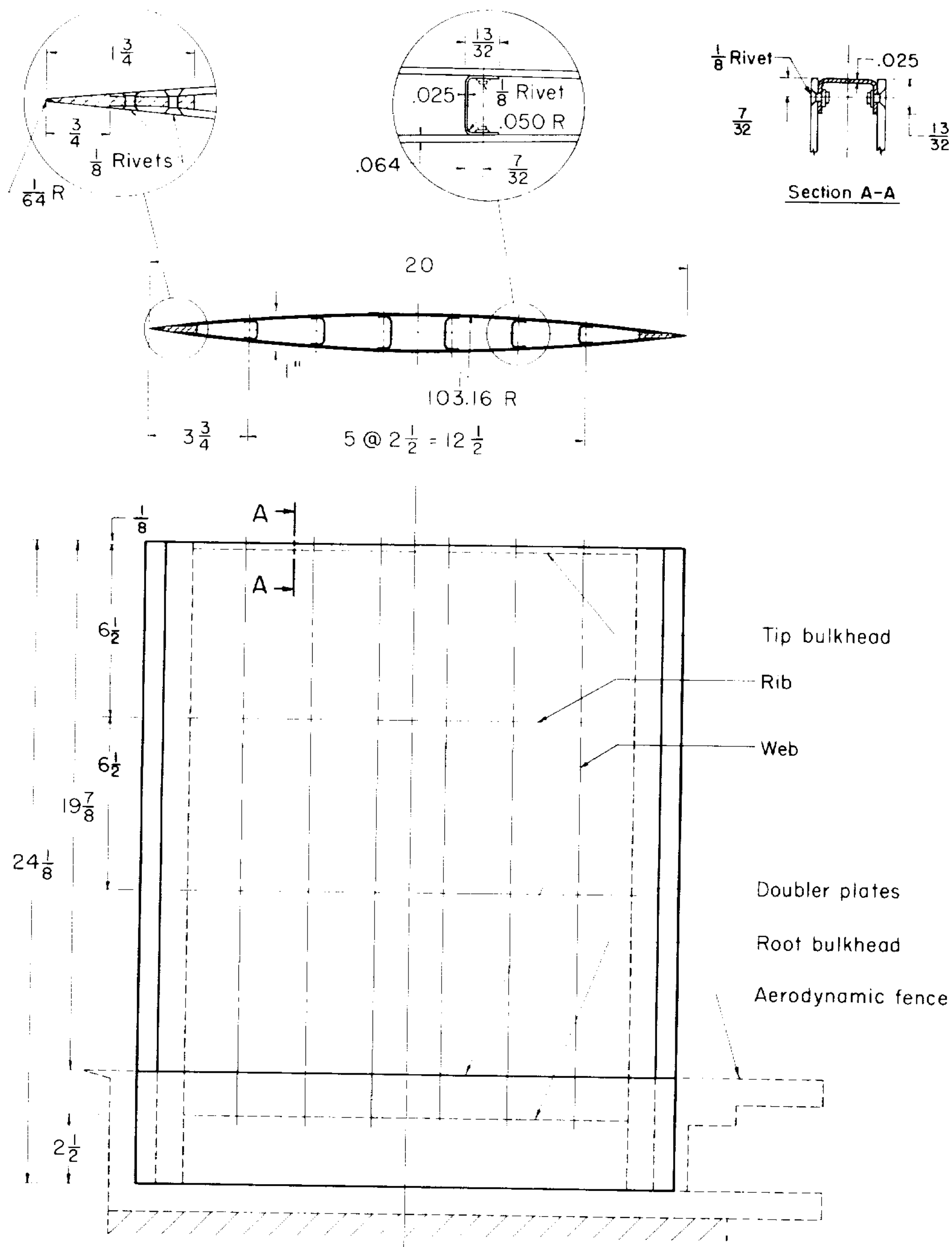
[redacted]




(c) Model MW-16.

Figure 1.- Continued.

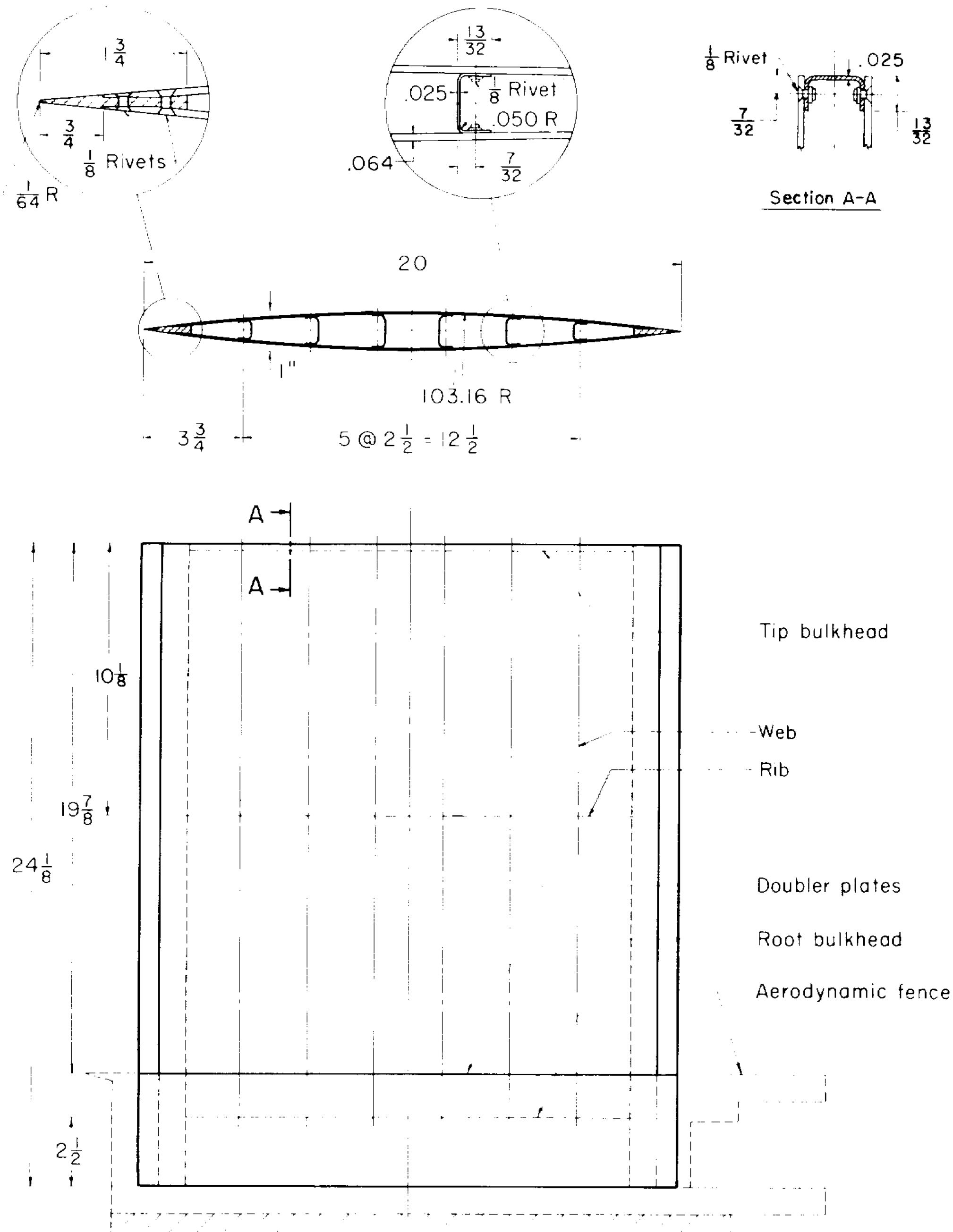
[redacted]




(d) Model MW-17.

Figure 1.- Continued.

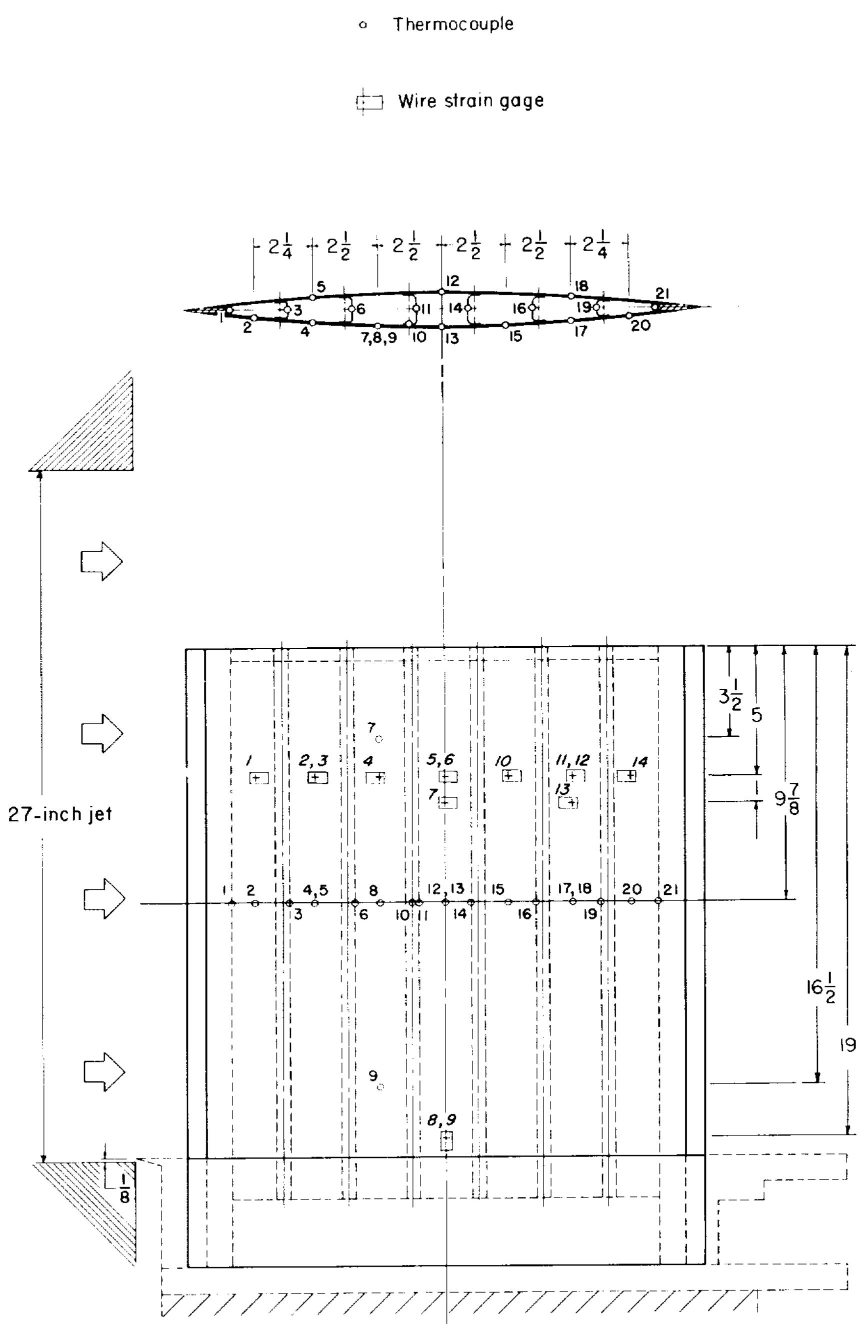
[redacted]




(e) Model MW-18.

Figure 1.- Concluded.

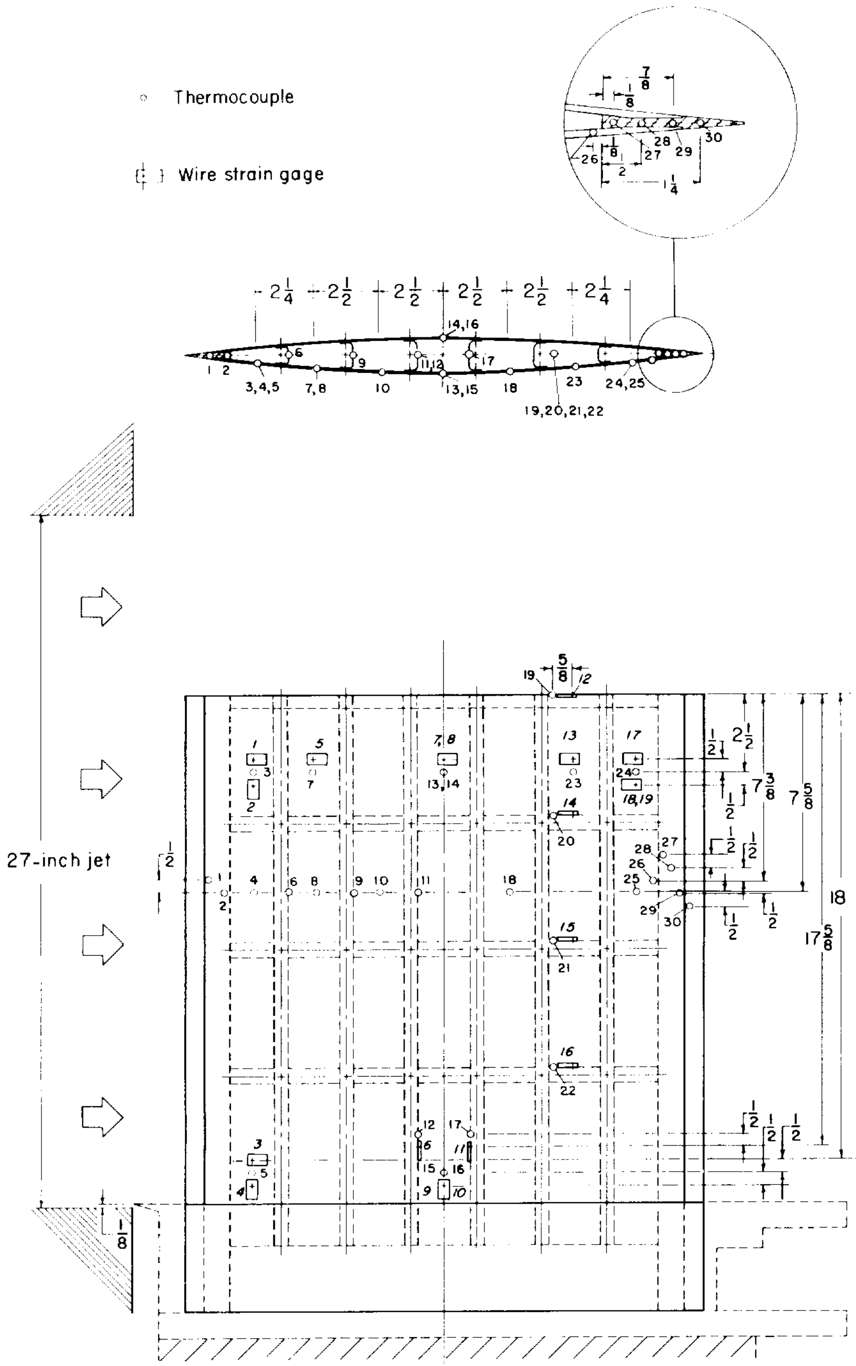
[redacted]




(a) Models MW-2-(4) and MW-4-(3).

Figure 2.- Location of instrumentation for models. (Where two wire gages are listed, the second is on far skin.)

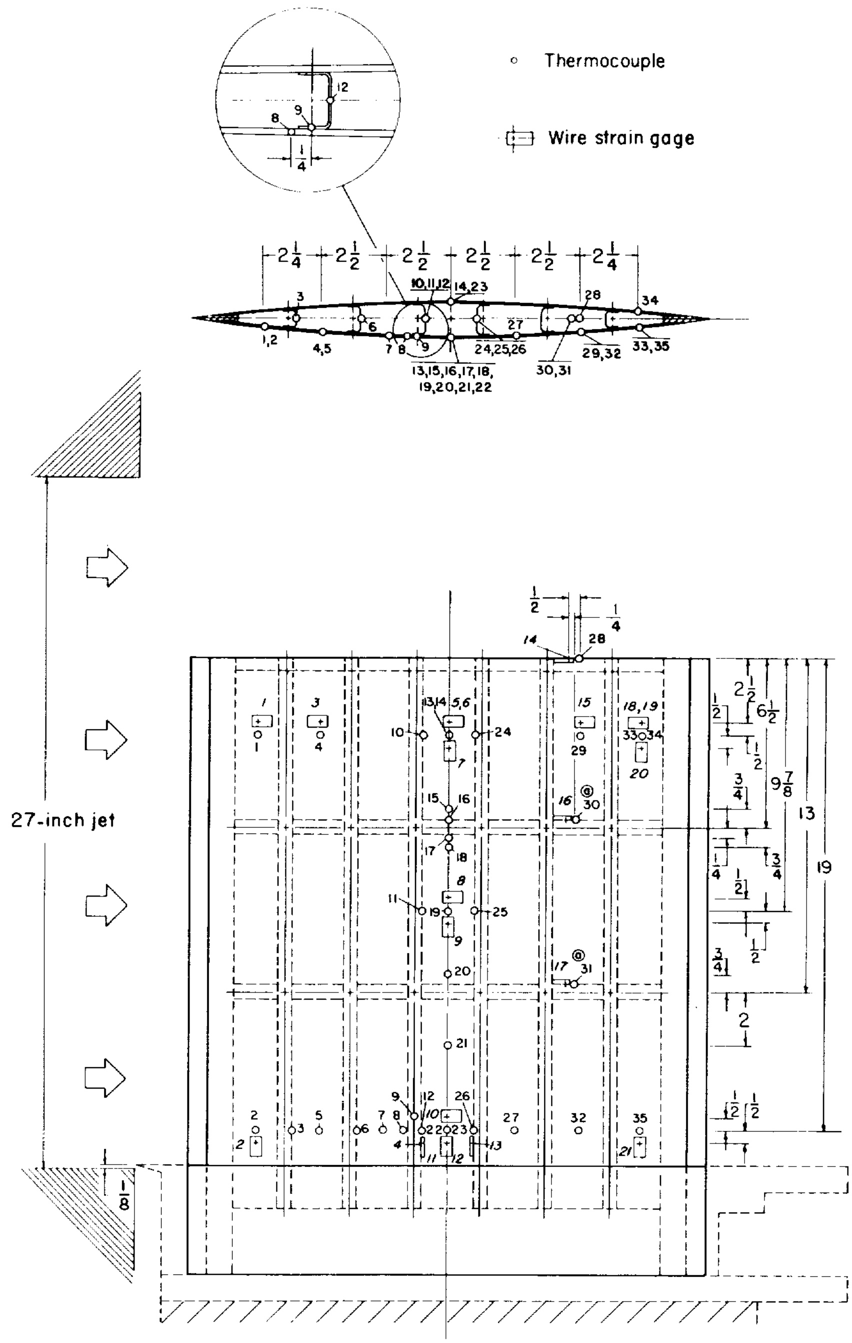
[redacted]




(b) Model MW-16.

Figure 2.- Continued.

[redacted]



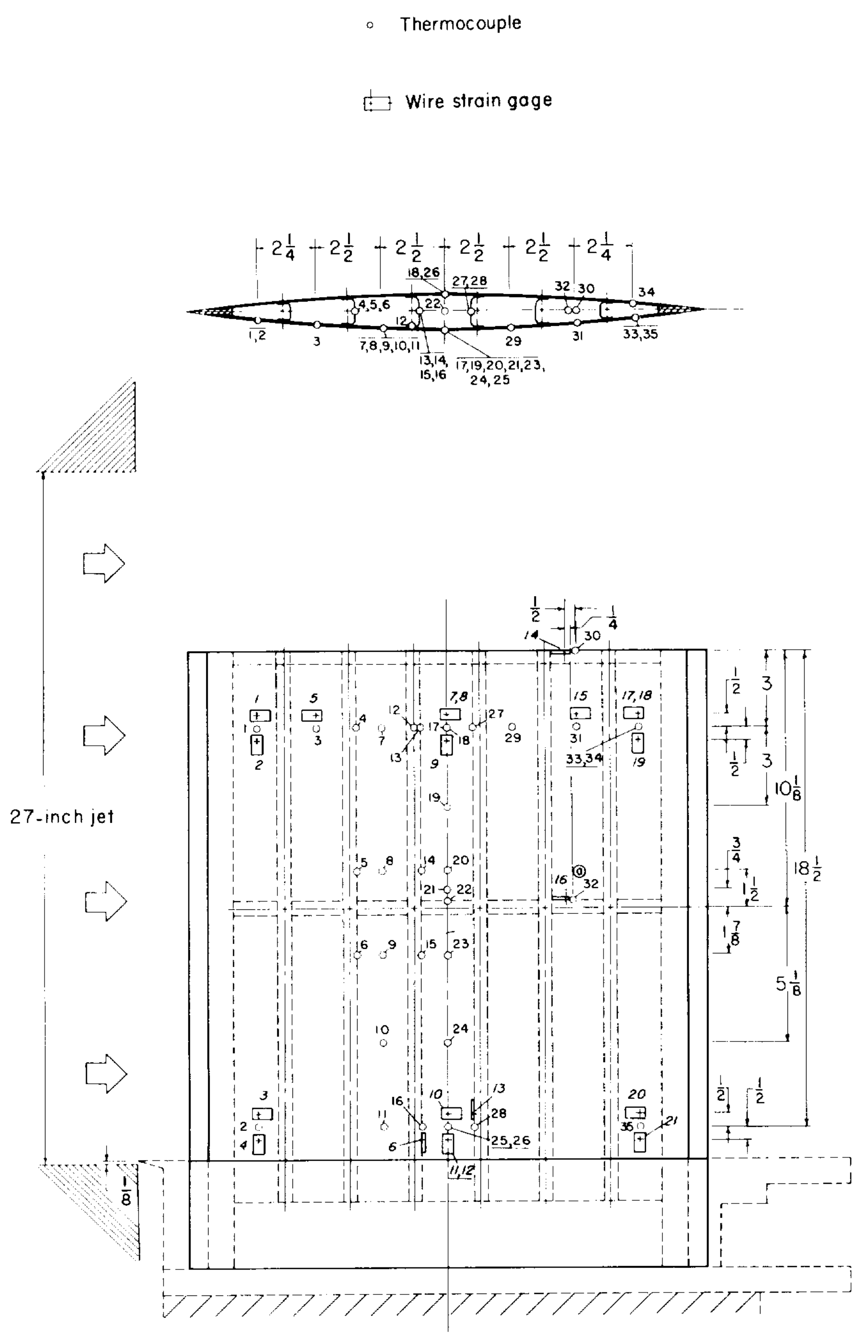

(c) Model MW-17.

Figure 2.- Continued.

[redacted]

[redacted]



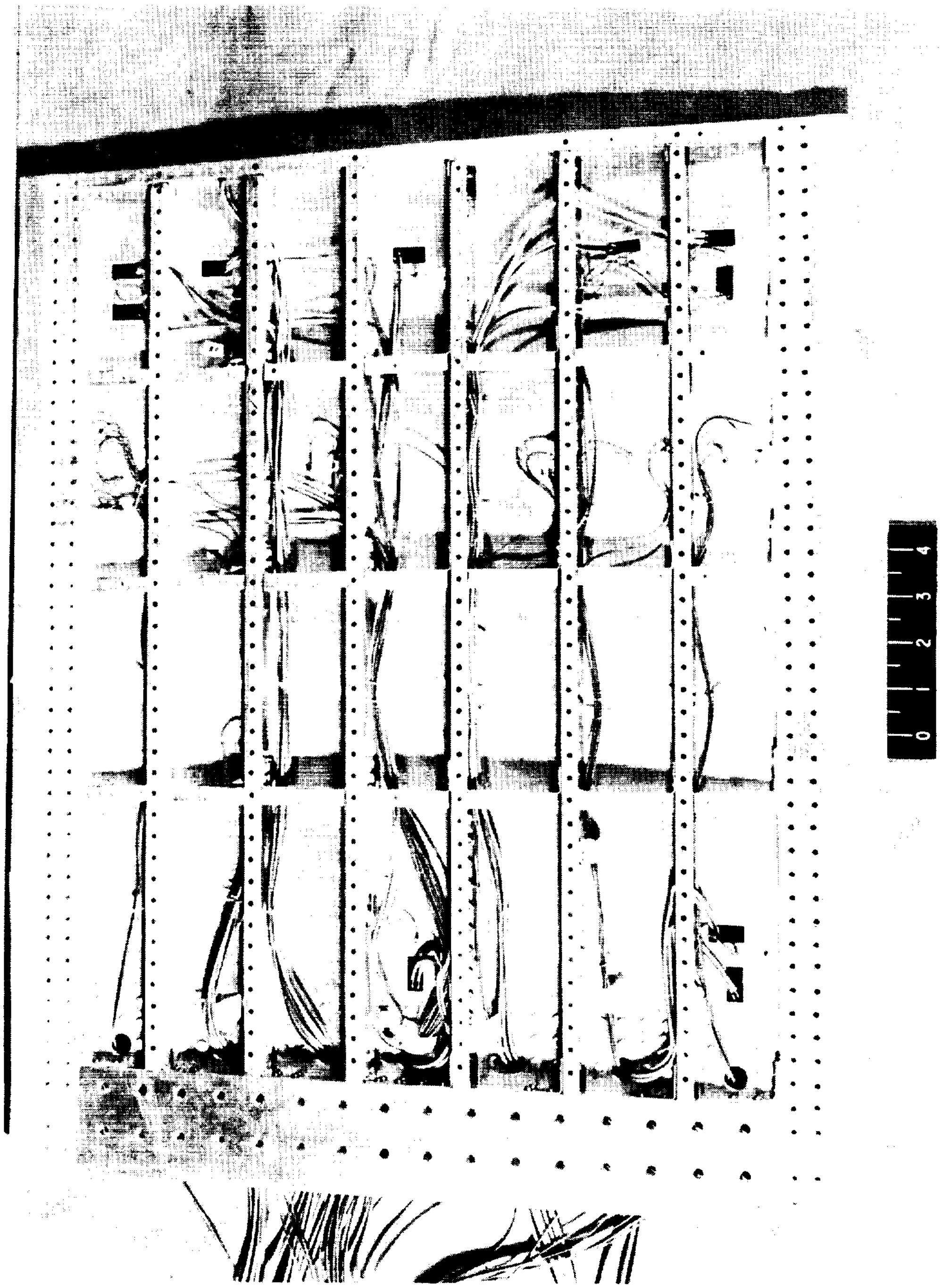



(d) Model MW-18.

Figure 2.- Concluded.

[redacted]

[redacted]



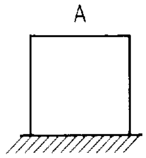
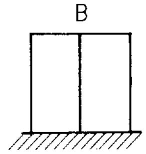
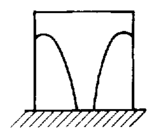
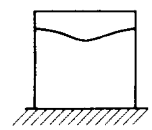
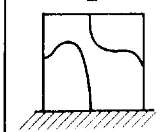

L-80729

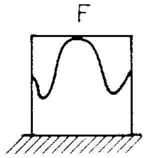
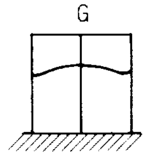
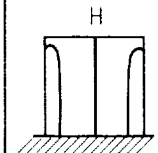
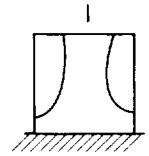
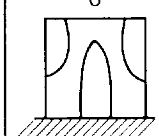
Figure 3.- Photograph of instrumentation of model MW-16 prior to final assembly.

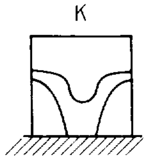
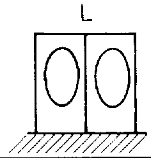
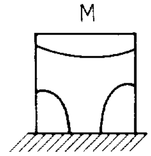
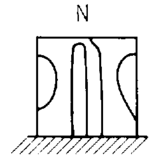
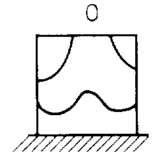
[redacted]

[redacted]



| Model | Frequency, cps, for node line[a] | | | | |
|---|---|---|---|---|---|
| | A  | B  | C  | D  | E  |
| MW-2-(4) | 68 | 147 | 273 | – – – | 351 |
| MW-4-(3) | 71 | 149 | 277 | – – – | 348 |
| MW-16 | 59 | 148 | – – – | 300 | – – – |
| MW-17 | 73 | 155 | – – – | 333 | – – – |
| MW-18 | 71 | 152 | – – – | 318 | – – – |

| Model | F  | G  | H  | I  | J  |
|---|---|---|---|---|---|
| MW-2-(4) | 408 | – – – | 450 | – – – | 535 |
| MW-4-(3) | 392 | – – – | 430 | – – – | 535 |
| MW-16 | – – – | 423 | – – – | 527 | – – – |
| MW-17 | – – – | 431 | – – – | 522 | – – – |
| MW-18 | – – – | 404 | – – – | 450 | – – – |

| Model | K  | L  | M  | N  | O  |
|---|---|---|---|---|---|
| MW-2-(4) | – – – | 590 | – – – | 665 | 732 |
| MW-4-(3) | 569 | 582 | – – – | 661 | 715 |
| MW-16 | – – – | – – – | 668 | – – – | 727 |
| MW-17 | – – – | – – – | 653 | – – – | 737 |
| MW-18 | – – – | – – – | 567 | – – – | 740 |

[a]Modes shown are composites from modes for all models. Individual modes varied slightly from those shown.

Figure 4.- Natural frequencies and nodal patterns (A to O) of models at room temperature.

[redacted]

[redacted]

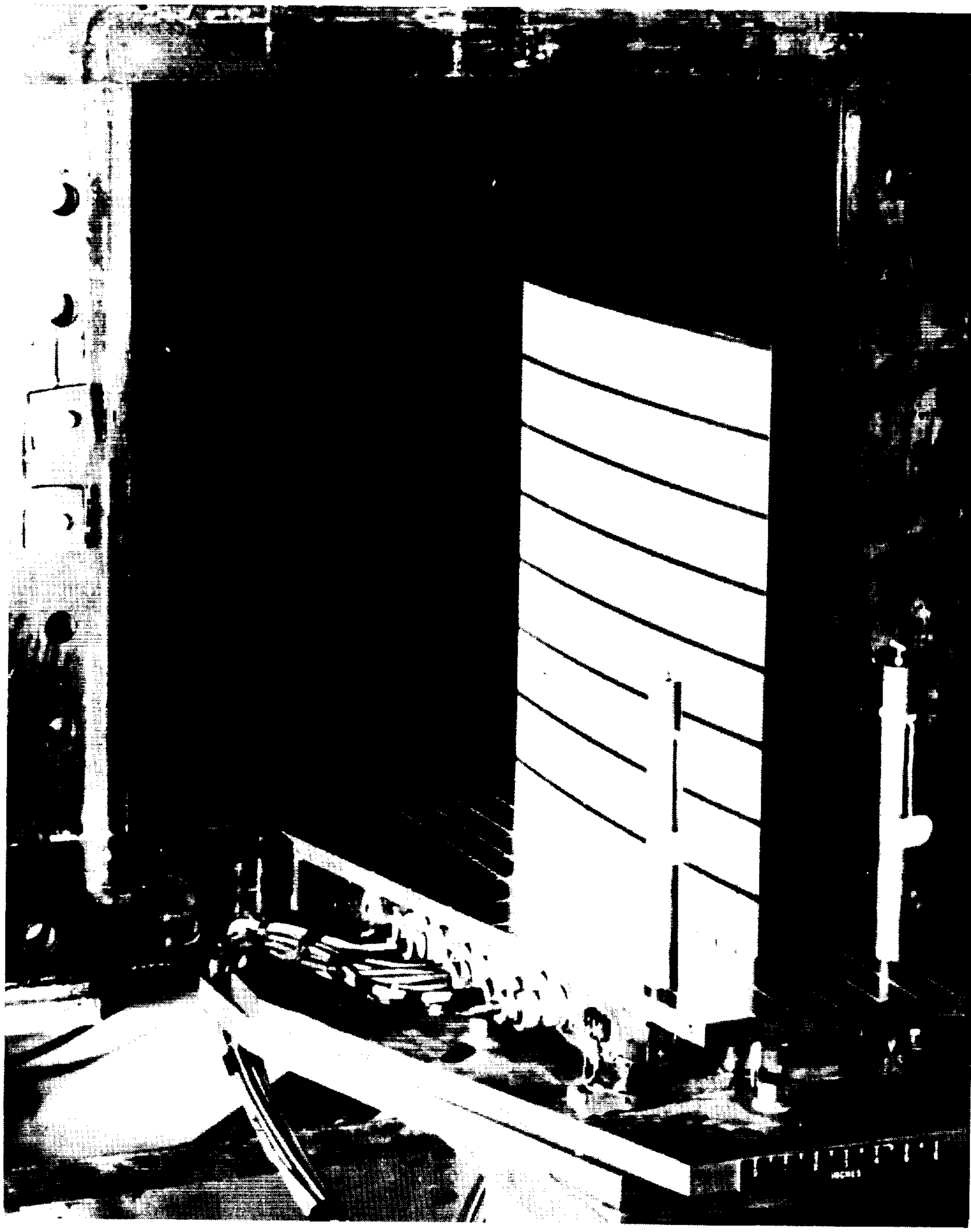
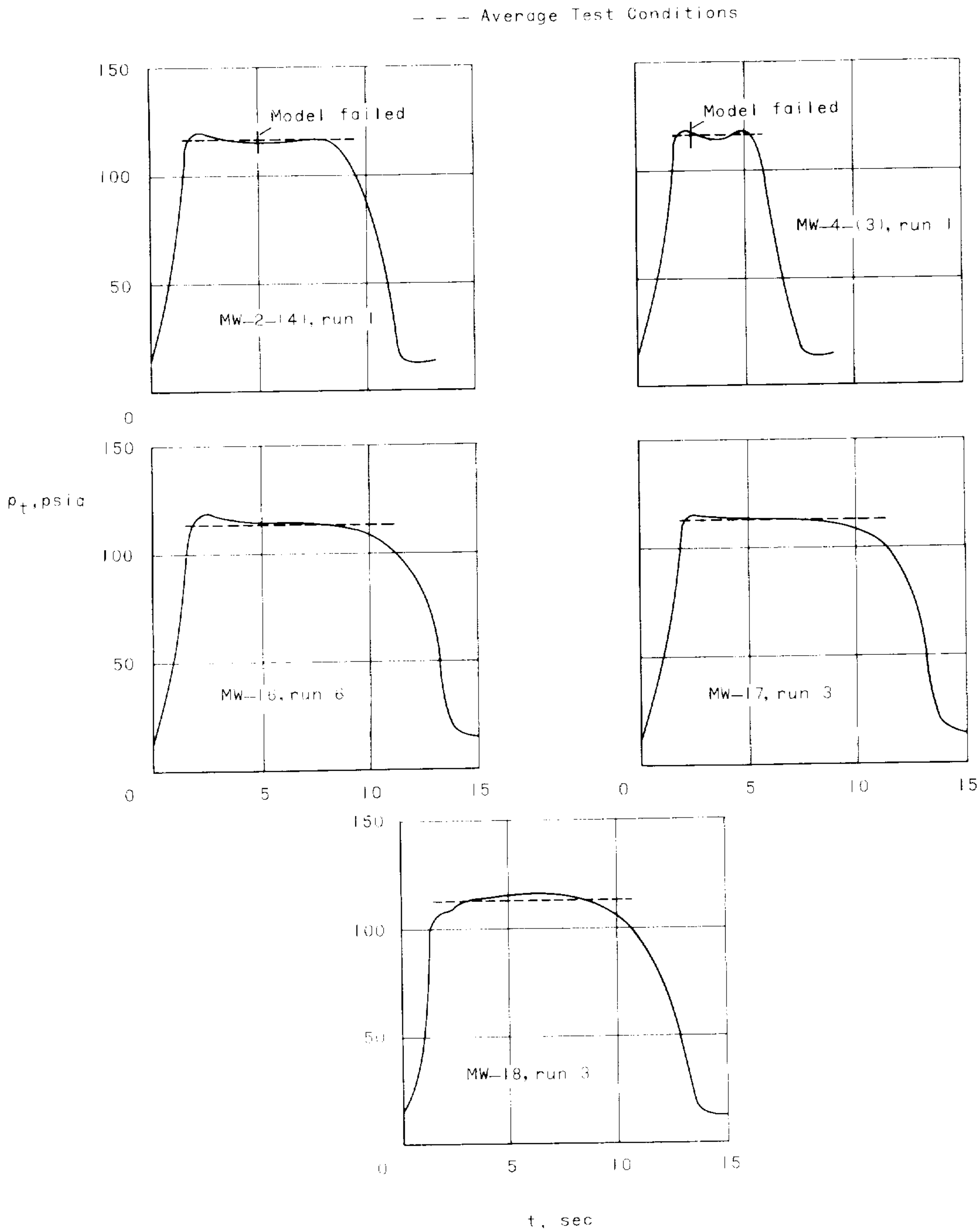


Figure 5.- Model in place at nozzle exit prior to test. L-81922

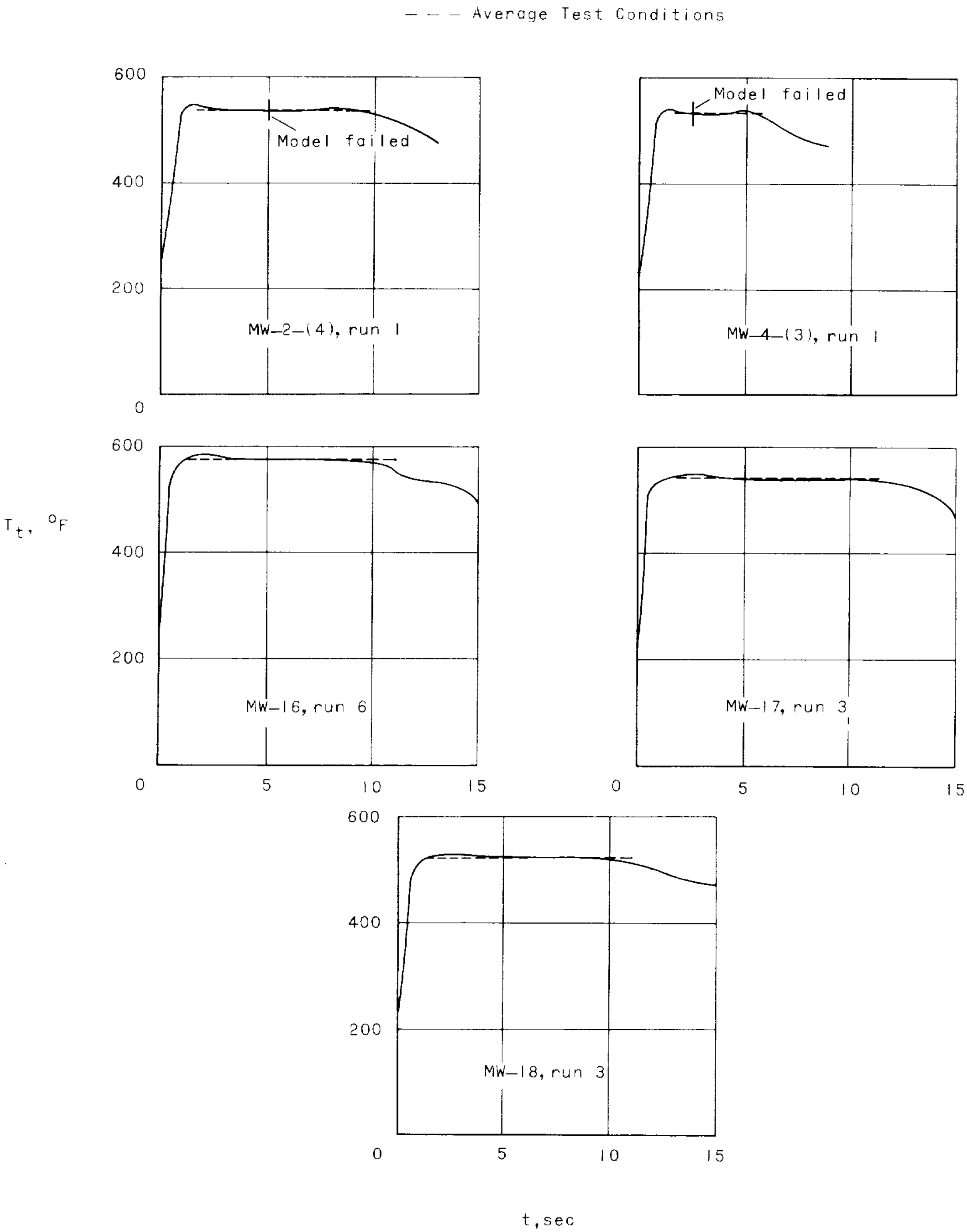
[redacted]




(a) Pressure.

Figure 6.- Tunnel stagnation pressure and temperature histories.

[redacted]




(b) Temperature.

Figure 6.- Concluded.

[redacted]

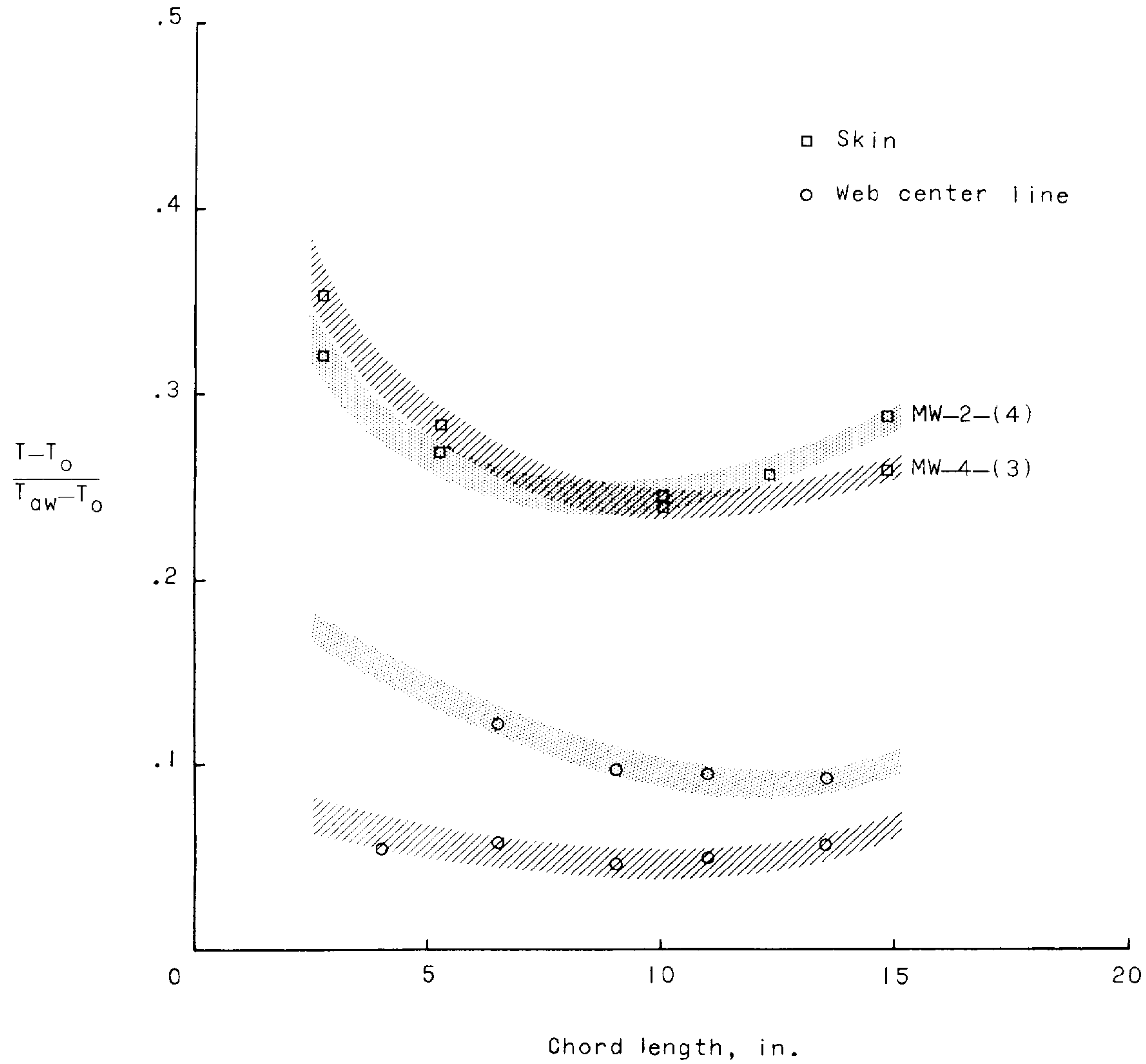



Figure 7.- Chordwise dimensionless temperatures for models MW-2-(4) and MW-4-(3) at 2 seconds.

[redacted]

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TESTS OF AERODYNAMICALLY HEATED MULTI-WEB WING STRUCTURES IN A FREE JET AT MACH NUMBER 2. FIVE ALUMINUM-ALLOY MODELS OF 20-INCH-CHORD WITH 0.064-INCH-THICK SKIN, 0.025-INCH-THICK WEBS, AND VARIOUS CHORDWISE STIFFENING AT 2° ANGLE OF ATTACK. Donald H. Trussell and Robert G. Thomson. January 1960. 33p. diagrs., photos., tabs., film suppl. available on request.
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An experimental study was made on five 2024-T3 models under simulated supersonic flight conditions. One model with no internal chordwise ribs failed dynamically part way through its test; another model with no chordwise ribs experienced a static bending type of failure early in its test while undergoing flutter; and the three remaining models with one, two,
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